

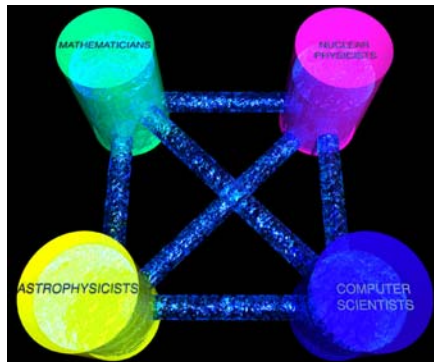
TeraScale Supernova Initiative

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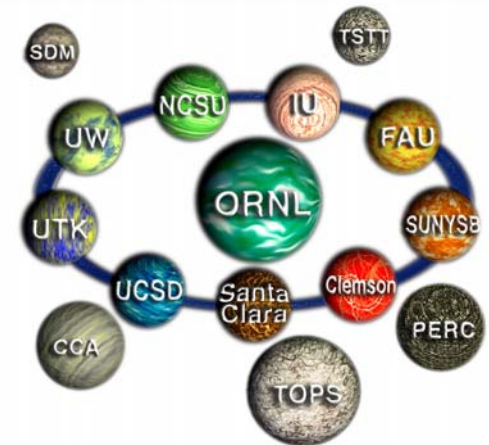
www.tsi-scidac.org

11 Institution, 21 Investigator, 34 Person, Interdisciplinary Effort

- ⇒ *ascertain the core collapse supernova mechanism(s)*
- ⇒ *understand supernova phenomenology*
 - *e.g.: (1) element synthesis, (2) neutrino, gravitational wave, and gamma ray signatures*
- ⇒ *provide theoretical foundation in support of OS experimental facilities*
- ⇒ *develop enabling technologies of relevance to many applications*
 - *e.g. 3D, multifrequency, precision radiation transport*
- ⇒ *serve as computational science testbed*
 - *drive development of technologies in simulation “pipeline”*
(data management, networking, data analysis, and visualization)



*With ISIC and other collaborators:
89 people from 28 institutions involved.*



Core Collapse Supernovae as Element Factories

1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu	
87 Fr	88 Ra	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr	

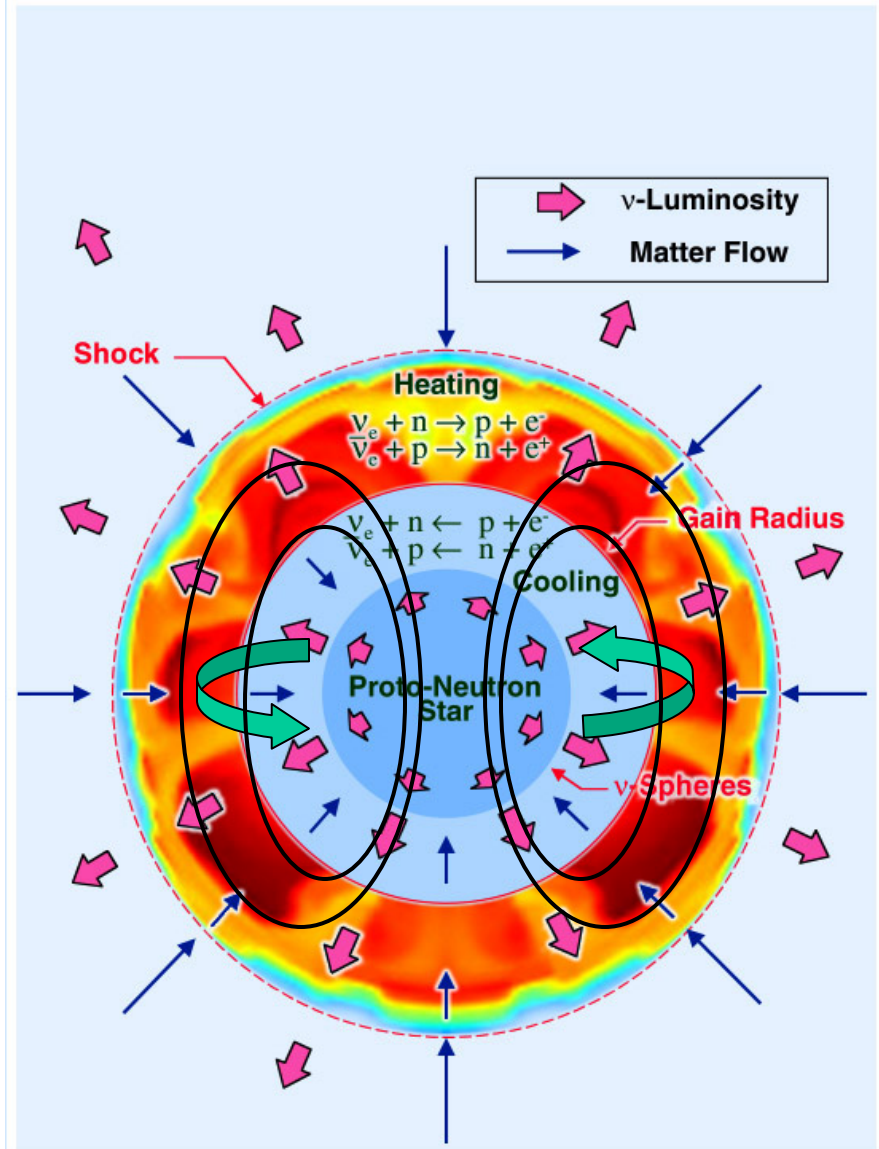
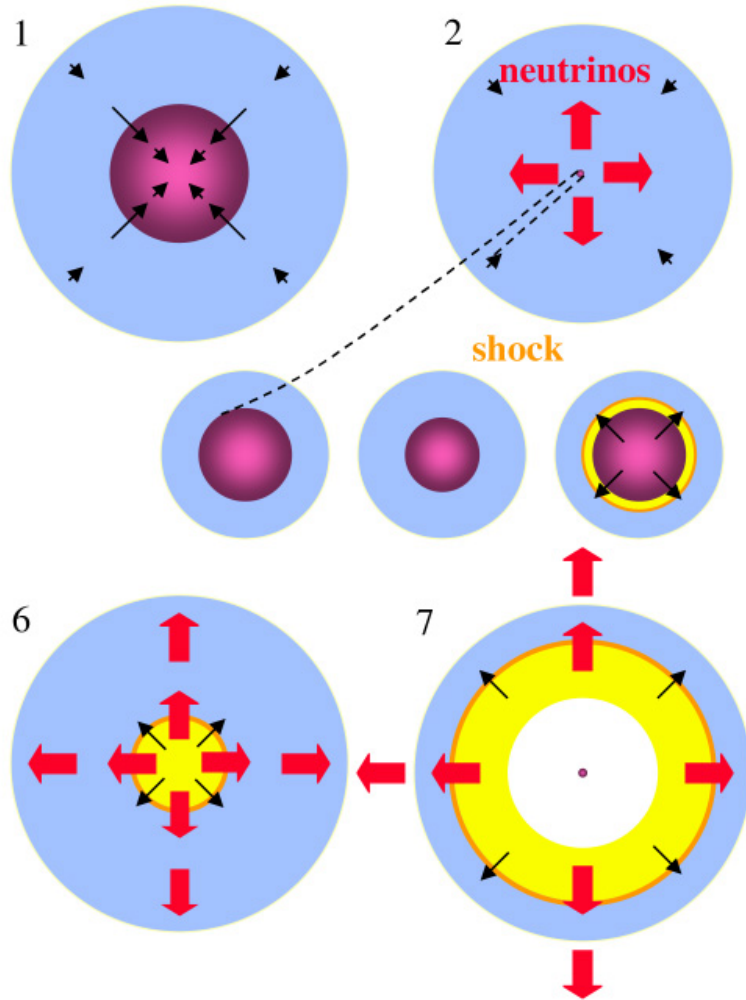
Core collapse supernovae are the dominant source of the elements between oxygen and iron. Believed to be responsible for half the elements heavier than iron.

Single most important source of the elements in the Universe.

Requirements and Approach

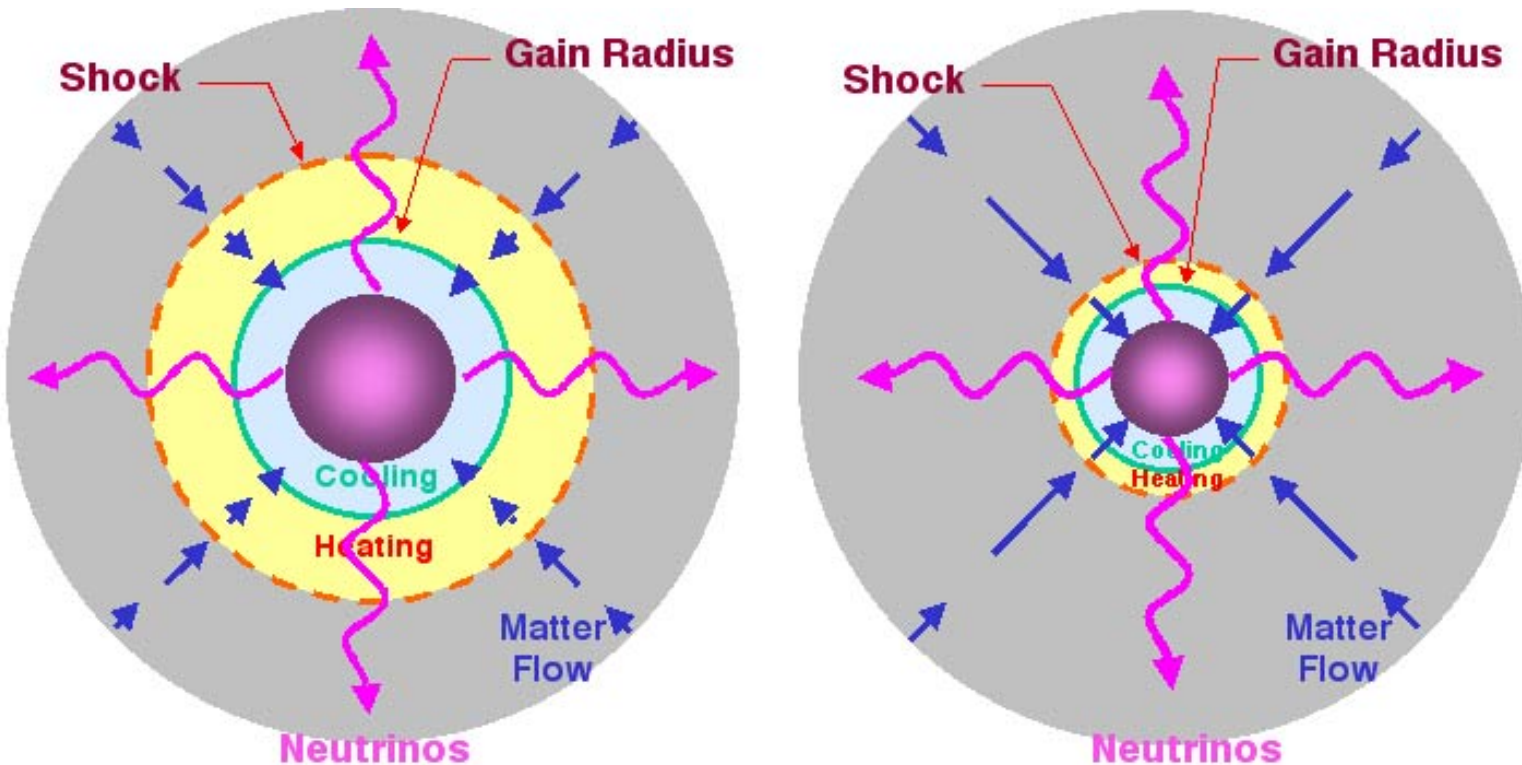
Anatomy of a Supernova

Core Collapse and Explosion

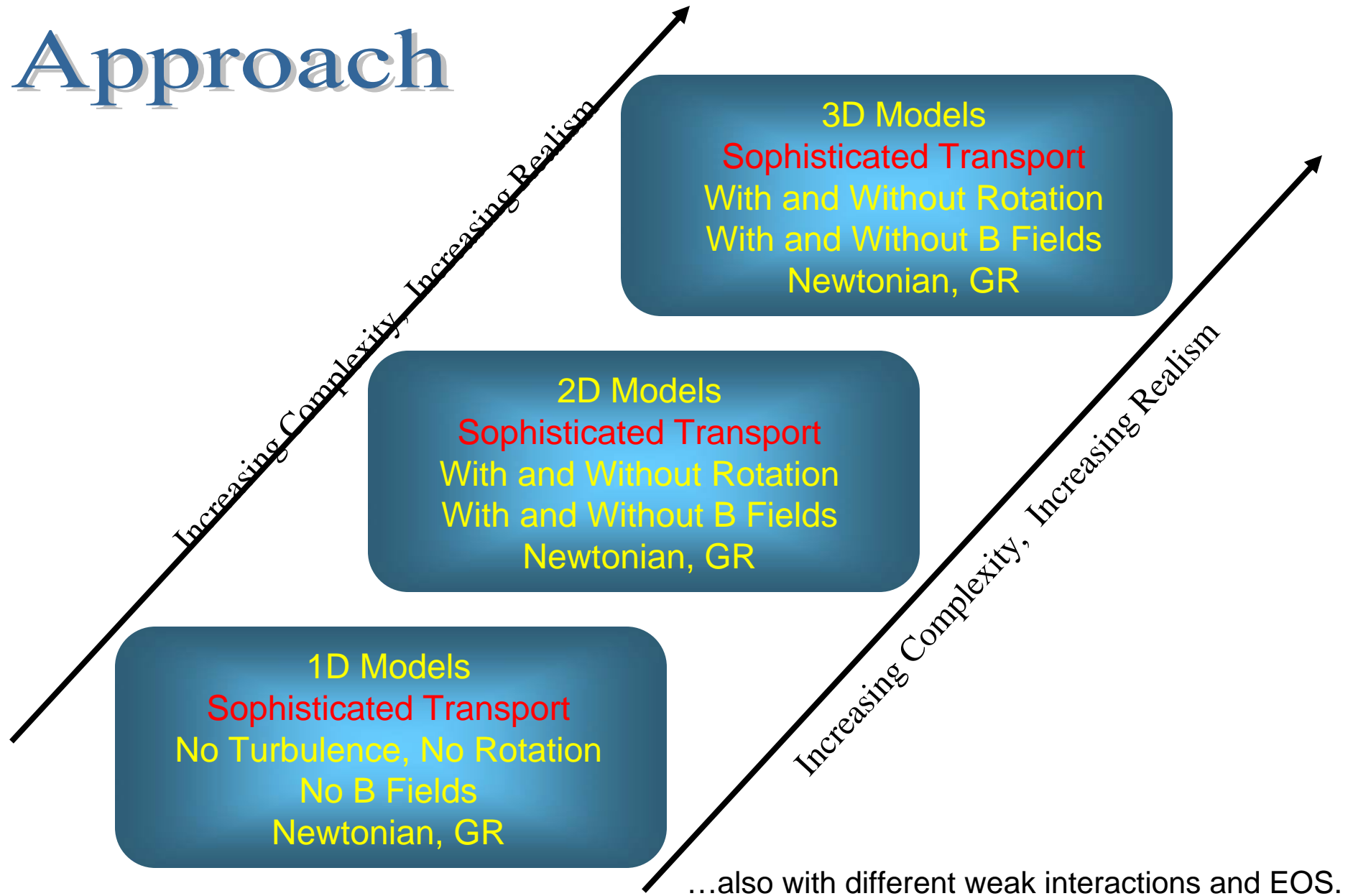


Newtonian Versus GR

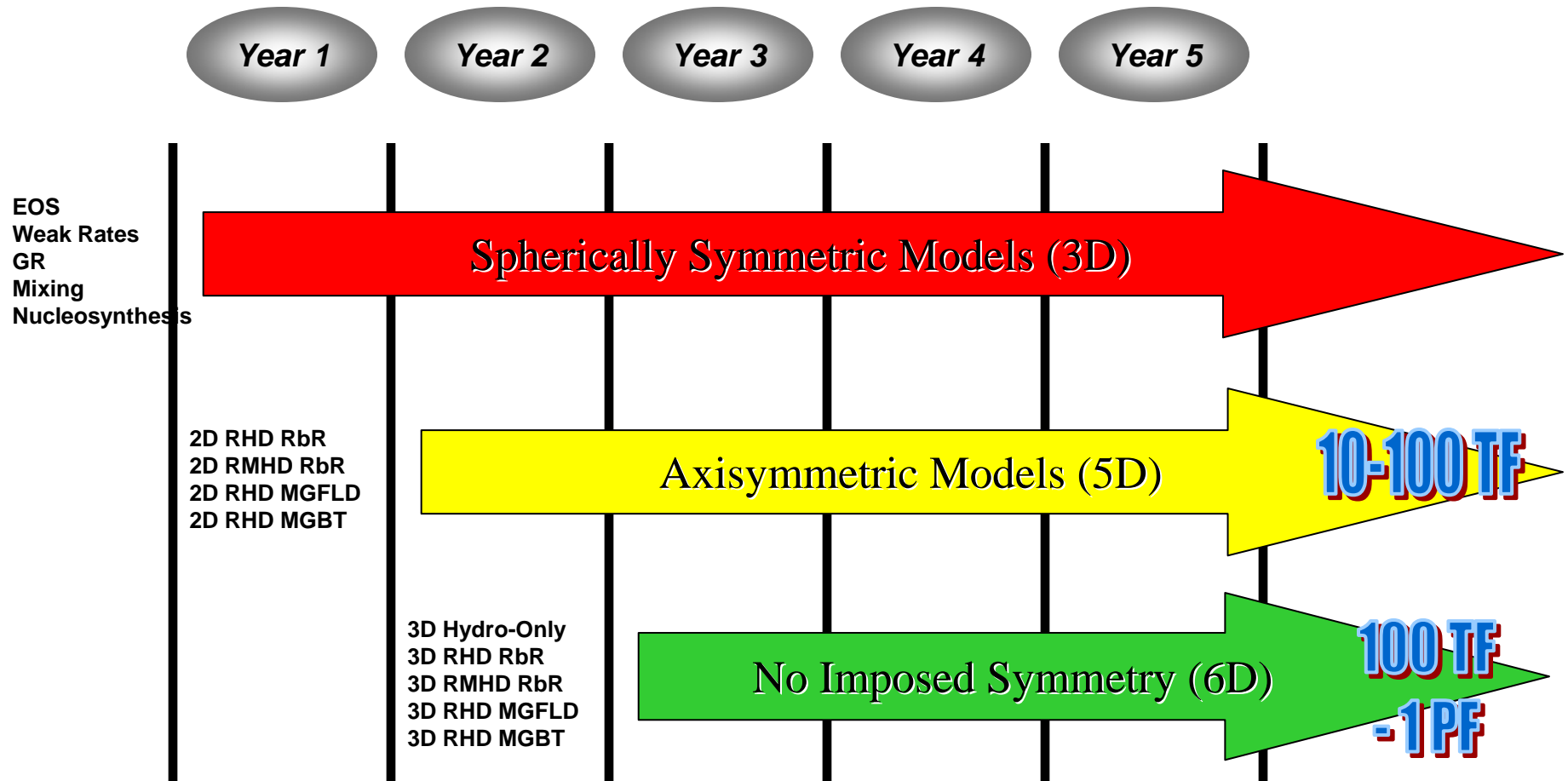
A comparison of key radii in a Newtonian versus a general relativistic model (25 Solar Masses):

Bruenn, DeNisco, and Mezzacappa (2001)

Approach



Simulation Timelines



Discovery Through NLCF/NCCS Resources

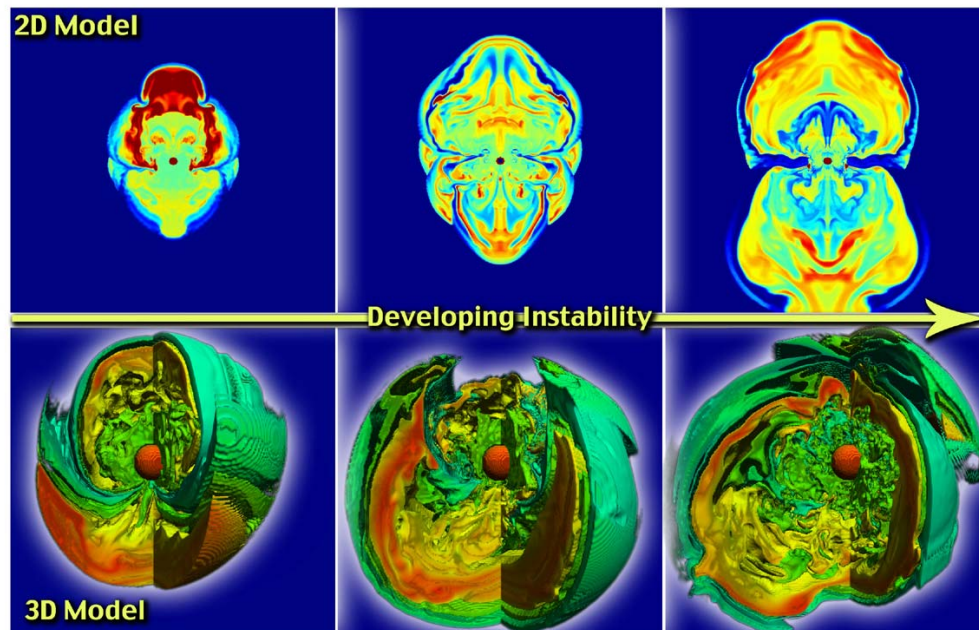
Stationary Accretion Shock Instability (SASI)

New ingredient in supernova theory.

Relevance:

Explosion Mechanism

Observables



Blondin, Mezzacappa, and DeMarino (2003)

Confirmed by:

- ⇒ Janka et al. 2004
- ⇒ Scheck et al. 2004
- ⇒ Ohnishi et al. 2005

Buras et al. (2003) Physics

Parameterized neutrino heating/cooling.

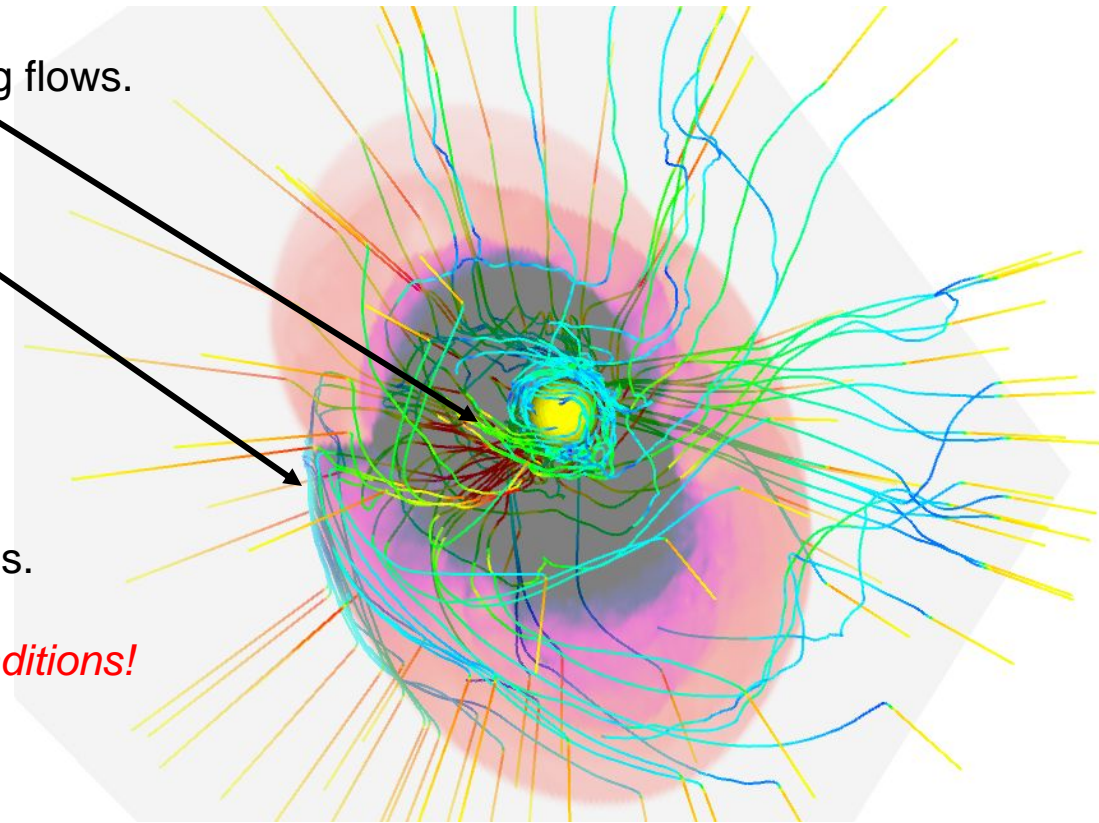
SASI-Induced Spin

SASI-induced counter-rotating flows.

★ *35 ms spin period.*

⇒ Consistent with observations.

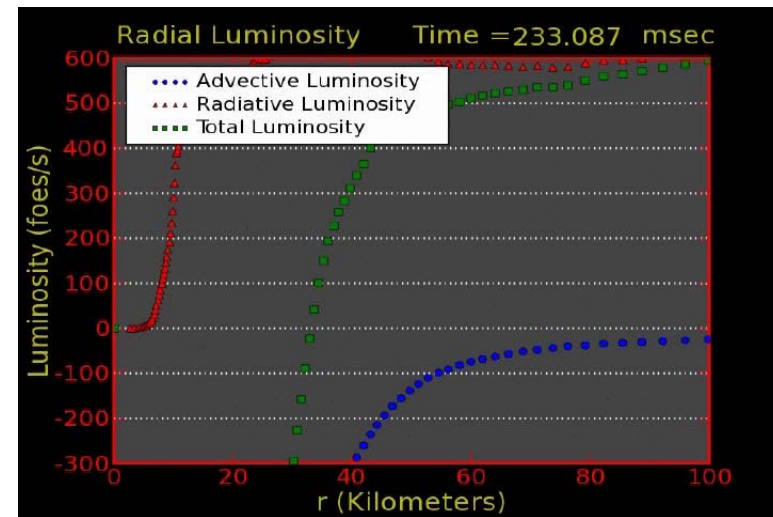
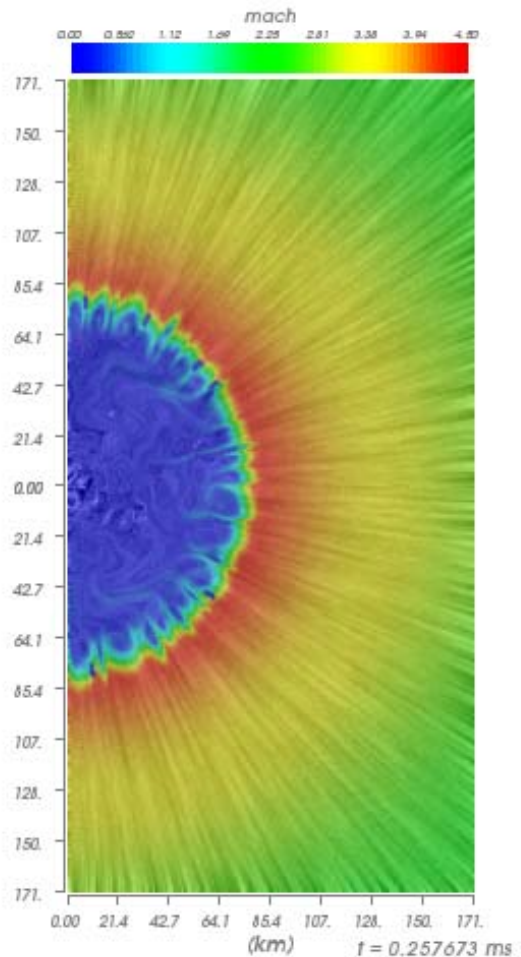
★ *Spherically symmetric initial conditions!*



Blondin and Mezzacappa (2005)

Discovery Through NERSC Resources

First Realistic 2D Supernova Models



- *First 2D models to be able to explore PNS instabilities in the context of nonlinear numerical simulations.*
- *First fully 2D models to explore explosion mechanism.*

Swesty and Myra (2005)

"Enabling Technologies"

Linear/Nonlinear Systems Underpinning Neutrino Transport Equations

Progress (in conjunction with **TOPS**):

2D/3D MGFLD

- ➡ Sparse Approximate Inverse Preconditioner
Saylor, Smolarski, and Swesty (2004)

⇒ Successfully implemented in 2D MGFLD code (V2D).

- ➡ Implicit Hydrodynamics (Reynolds, Woodward, Swesty, Myra)

2D/3D Boltzmann Transport

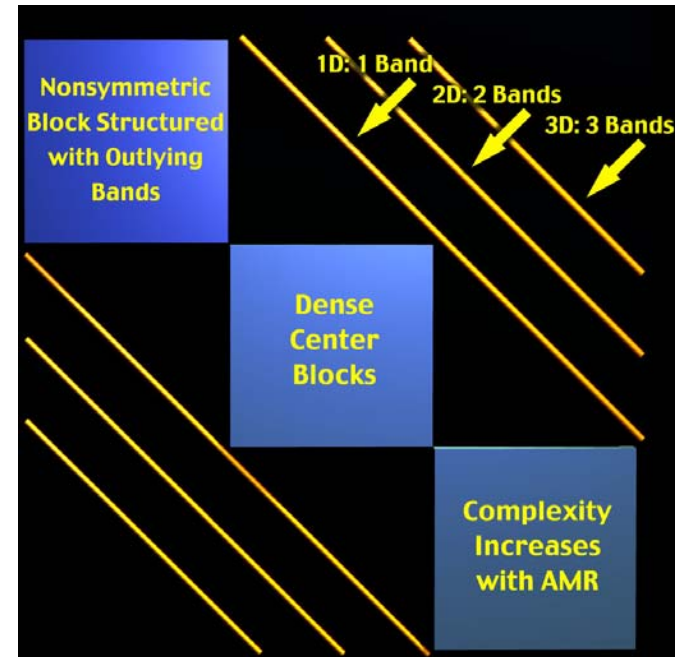
- ➡ “ADI” Preconditioner
D’Azevedo et al. (2004)

⇒ Successfully implemented in 1D Boltzmann code (AGILE-BOLTZTRAN).

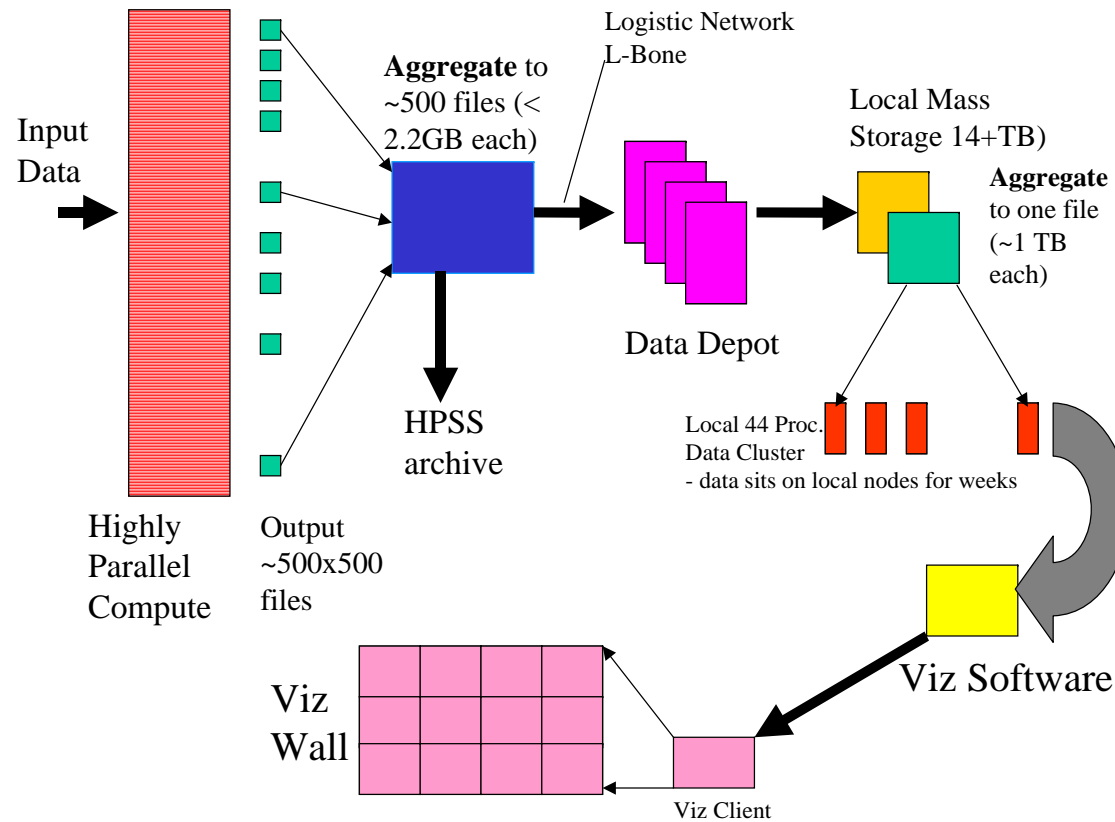
- Dense LU factorization was used for dense blocks (D’Azevedo).

⇒ Being implemented in 2D/3D Boltzmann code (GenASiS).

- Sparse incomplete LU factorization for dense blocks (D’Azevedo, Eijkhout).

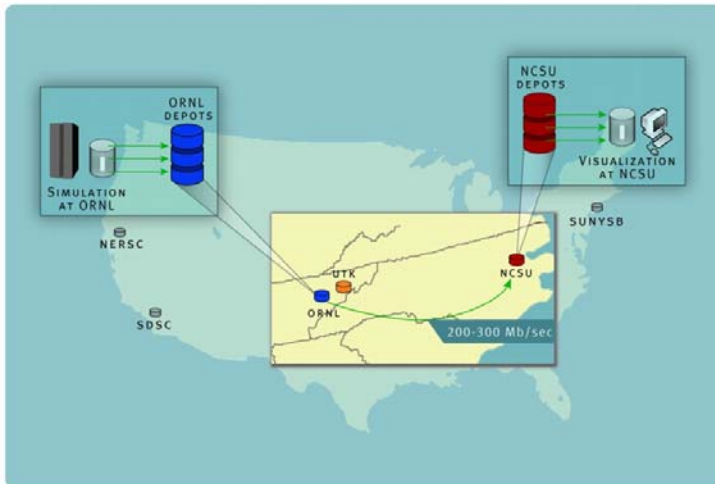


TSI Workflows



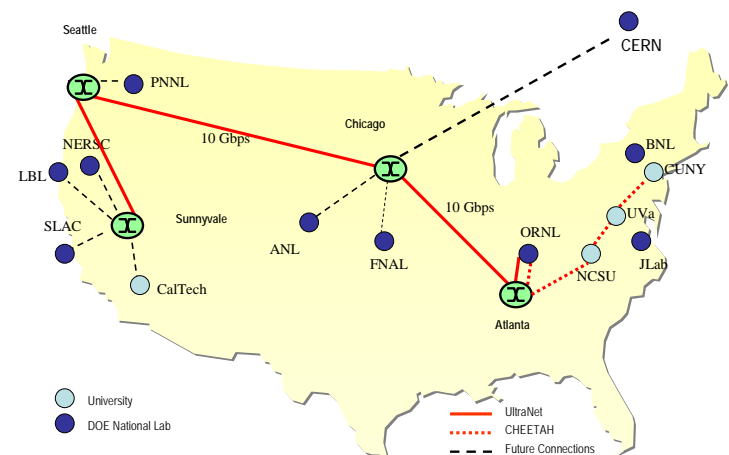
Novel networking approaches on “existing” networks.

- Successfully deployed TSI “Logistical Network.”
- Throughputs allowed transfer of TeraBytes of simulation data.



Novel networking approaches on “dedicated” networks.

DOE Science UltraNet + NSF CHEETAH



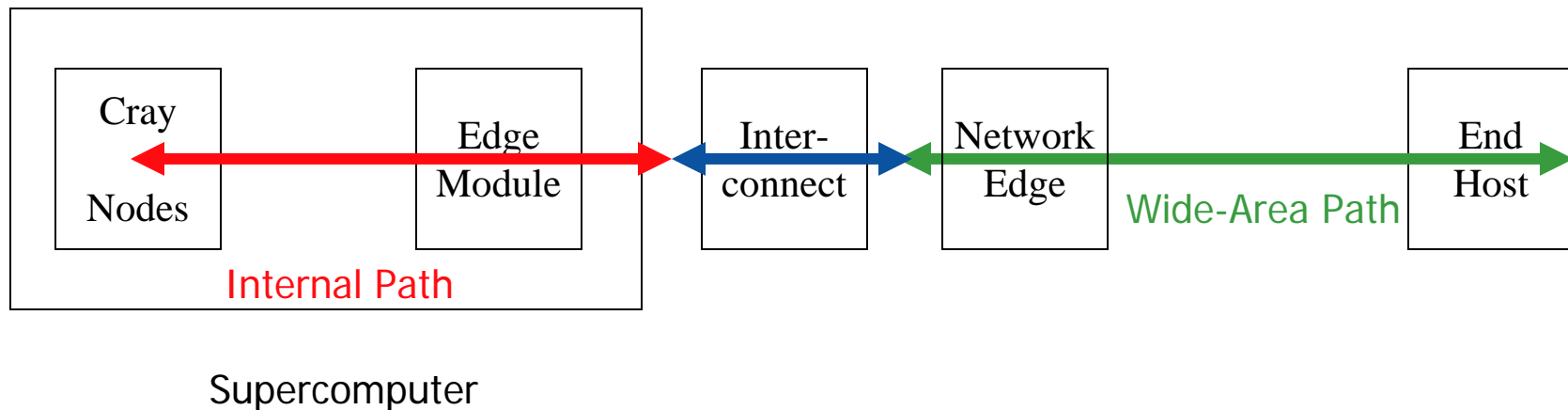
Beck

Rao

- TSI served as testbed for NSF funded Cheetah project.
- Provisioning and protocols for dedicated, high-bandwidth networks.

"Impedance Matching" Across Heterogenous Networks

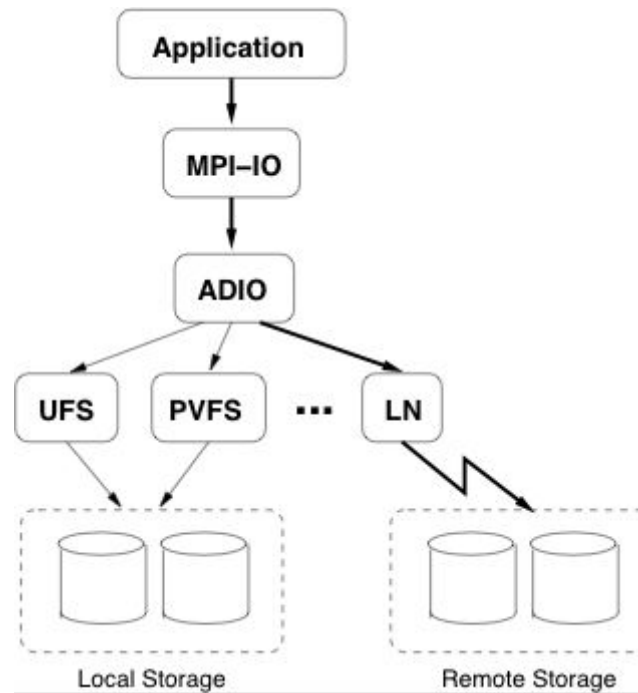
Rao



Focus on

- ⇒ internal supercomputer network,
- ⇒ wide-area network,
- ⇒ and interconnect.

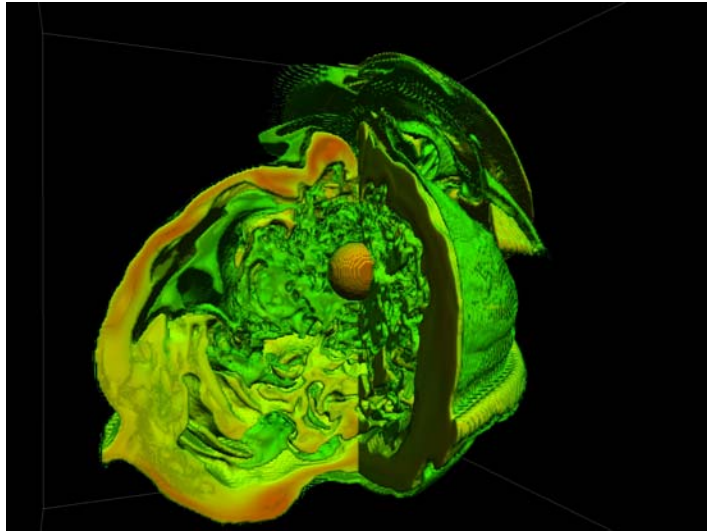
Parallel I/O



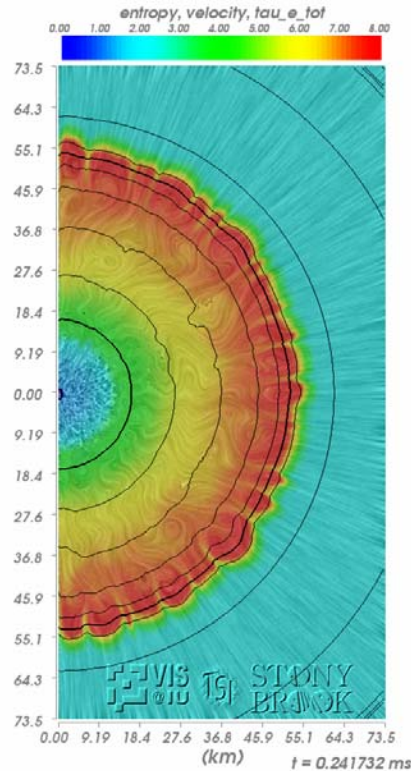
Enable parallel I/O out to the Logistical Network.

Ross, Lee

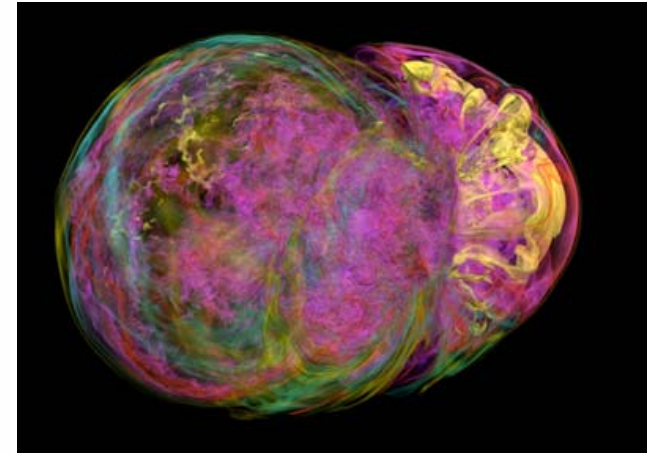
Visualization



Toedte

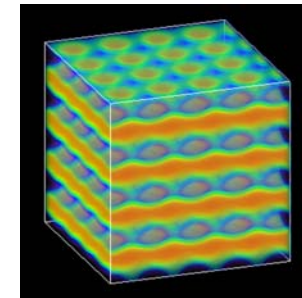
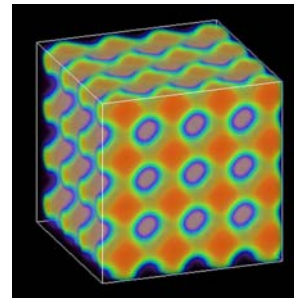
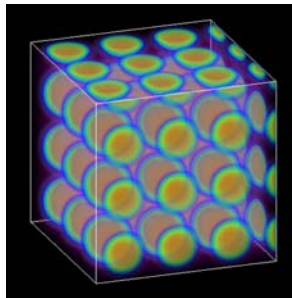


Baker, Bachta



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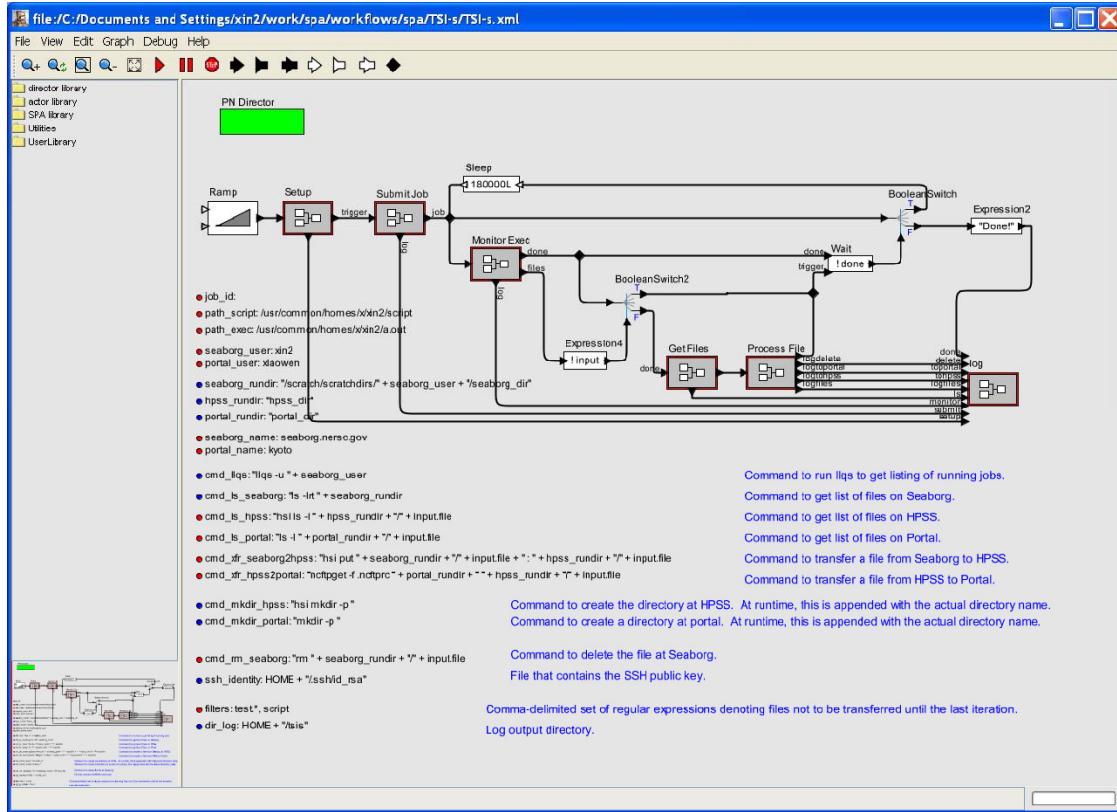
- *Micro/Macro Scales*
- *New Techniques*
- *Surface/Volume*
- *Hardware/Software*
- *Interactivity*



Shen, Wang

Progress Toward Automating Workflows

SUNYSB Workflow



Critchlow

NCCS/NLCF/NERSC Enabled

Sophisticated 2D models emerging.

3D models already bringing surprises.

Simulation lines enabled by close coupling
with applied mathematicians and computer scientists.

10-Year Roadmap:
3D Newtonian (5 YRS)
3D General Relativistic (10 YRS)